We appreciate the constructive comments and detailed suggestions, which have helped us improve the quality of the manuscript.

Below are our detailed point-by-point responses (in blue) to each comment (in black).

Please note that all line numbers mentioned in our responses correspond to the "Track change verison" in the revised manuscript. Additionally, to prevent any errors or confusion with line numbers, for certain comments, we have directly copied and pasted the revised text into our responses.

Page 1

Line 21: distinctly different seasonal influences on the proxies.

We have updated this sentence following the suggestion (line 21).

Line 22: ~~reflecting summer temperatures~~

We agree with the suggestion and have deleted the section (line 22).

Page 3

Line 85: Is the effects of winds solely restricted to the ocean surface? Consider to delete "and wind patterns"

We aim to express that on a seasonal scale, winds are a major factor leading to seasonal temperature differences. In comparison, subsurface waters are less responsive to these seasonal changes, especially in open ocean areas rather than upwelling regions. Because wind patterns are considered an important factor in generating significant seasonal differences in this study, we have chosen to retain this term. We have rephrased the sentence to improve the clarity as follows (Line 83-84):

"In contrast to SST, which is highly responsive to seasonal forcing factors such as solar radiation and wind patterns, SubT exhibits minimal seasonal variability."

Line 89: ...different climatic factors on their variations. - unclear, phrasing. Please rephrase to clarity and be more specific

The corresponding sentence has been rephrased for improving the clarity and be more specific as follows (Line 88-91):

"Given that the NAC transport occurs from the surface to depth (Daniault et al., 2016; Lozier, 2012), its variations should produce consistent effects in both SST and SubT. Therefore, the combined use of SubT and SST records could provide a more comprehensive identification of NAC-related changing signals, avoiding potential contrasting interpretation of NAC changes based solely on the seasonally biased SST records (e.g. Friedrich et al., 2013; Karas et al., 2020)."

Page 4

Line 102: re-drill

We have made the suggested change.

Line 103: Ridge. Four holes…

We have made the suggested change.

Line 107: which species?
The specific species now be listed (Line 110).

Line 108: measured
We have made the suggested change.

Page 5
Line 161: If the error of the calibration is so large and you don't really relate to the absolute temperatures, would it be better to only show the raw Mg/Ca data rather than the temperatures?

Although we don't relate to the absolute temperatures, the SubT's relatively change, which is independent to the error of the calibration, is an important information when discussing the NAC changes in Section 4.3.

Page 7
Line 186: ~~temperatures~~
We have deleted it.

Page 10-11
Line 255: I would keep the full name, but maybe the abbreviation is not needed since its given in the reference? I know the reviewer asked for a shortening here, but abbreviations should be defined.

We now include both the full name and the abbreviation when it is first introduced (Line 247).

Line 261: year 2000 AD
We have made the suggested change.

Line 262: year 2015 to 2000 AD
We have made the suggested change.

Line 262: may not be?
Due to the different time scales considered when comparing the overall warmer long term Pliocene responses and the modern, can you be certain that CO2 have no effect, or could it be that the SSTs are still adjusting to the forcing?

We realized that the previous expression about the relationship between CO2 and SST at Site U1313 is unclear and may misleading the effect of CO2 forcing. We have make corresponding changes as follow (Line 251-261).

"Notably, the CO_2 concentrations during the study interval in Pliocene are overall lower than the modern value of 369 ppm in 2000 AD (Fig. 4b; Lan et al., 2024). In comparison, the reconstructed SST records at Site U1313 are warmer than the average temperature for the period 2000 - 2015 AD (Fig. 4c). These observations indicate that CO_2 cannot solely explain the higher SST observed at Site U1313. This is in concert with the study by Fedorov et al. (2013), which showed that CO_2 is not necessarily the primary driver for a warmer Pliocene climate. In summary, we conclude that the northward expansion of warm water from STG is a

primary process that maintained the warmer-than-present SST observed at Site U1313 during the early Late Pliocene."

Page 11-13

Line 289: ... by comparing the pattern of variability between the alkenone and Mg/Ca based SST.

We realized the related sentence was unclear. While we did not use the exact wording suggested, we have rephrased the sentence to improve clarity. It now reads as follows (Line 284- 286):

"Compared to the uncertainty in interpreting absolute alkenone-based SST values for seasonal variations, we can draw more certain conclusions about the seasonal bias in its pattern of variability."

Line 290: variability seen
We have made the suggested change.

Line 290: suggests that the alkenone data represents a season different from summer.
We have made the suggested change.

Line 291-293: ~~In other words, whether the alkenone-SST in our study interval represents only spring or the annual mean in its values, its variation characteristics are certainly skewed towards a season opposite to the summer season indicated by the G. ruber Mg/Ca-based SST.~~
We have made the suggested change.

Line 294: , following Repenschläger et al. (2023).
We have made the suggested change.

Line 297: distinct different pattern of variability when comparing the Mg/Ca- and alkenone-based SST records...
We have made the suggested change.

Line 307: ice dynamics as in changes in ice volume/extent? or related to an assumption that when precession were lower you have larger ice sheets and more sea ice due to colder conditions?

Ice dynamics here refer to changes in ice volume and extent. We think the extent is more important than the volume when discussing the ice-albedo effect. For example, thin ice extent on the sea and land may not be large enough to significantly change the volume (i.e. the benthic d18O), but it is already sufficient to impact the ice-albedo effect.

Line 311: Even though there are traces of Pliocene sea ice, would it be enough to shift the westerlies far enough south to significantly impact U1313? With a glacial type Nordic Seas sea ice extent the southwesterlies are shifted southwards and in a more westerly direction, but how much of an effect can be expected in a Pliocene climate with limited sea ice and smaller ice sheets (and from the PlioMIP simulations a northward shift of the westerlies are suggested). Consider to acknowledge the uncertainties involved.

Considering the modern center of the westerlies is currently between approximately 30 and 60 ºN, it is unlikely that the location of U1313 (41ºN) was outside the range of the westerlies during our study interval, despite potential northward shifts of the westerlies during the warm Pliocene. Thus, any changes in the westerlies are able to impact the Site U1313.

The effect of ice albedo should be limited in summer, but its winter time variations can still have a significant impact on the SST of the mid- to high-latitude North Atlantic. An evidence supporting this come from Site 982 (58 ºN), where alkenone-based SST variability during the warm Pliocene is comparable to the glacial-interglacial variability of the Pleistocene. Lawrence et al. (2009) proposed same explanation related to the ice feedback mechanisms.

Further supporting evidence comes from the long-term evolution of SST and δ18O relationships, especially when we view it from the young to old age. As illustrated in Figure 6, during the early Pleistocene, both SST proxies exhibit synchronous changes with global ice volume (δ18O), displaying a clear obliquity cycle. This synchronicity suggests that ice-related feedback mechanisms, such as the southward shift of colder air and water masses during glacial times, impact both the summer and winter SST at Site U1313. Returning to our study interval in the warmer Pliocene, alkenone-based SST still maintains a synchronous relationship with δ18O, displaying an obliquity-dominated cycle, suggesting that the same ice-related feedback mechanisms are still effective during the cold season.

Line 332: Suggested rephrasing: In such cases, these two proxies can be considered representative for comparable oceanographic conditions. (ref).
We have made the suggested change.

Line 334-335: Unclear sentence. Suggested rephrasing:
For Example, if the pattern of variability is comparable one may expect that the signals reflect the same forcing responses, despite showing different absolute values.
We have made the suggested change.

Line 338: suggested rephrasing: ... meaning that each proxy provide information on different aspects of the climate system.
We have made the suggested change.

Page 15
Line 384: add reference to this statement.
I do not see how changes in sea ice should impact the benthic d18O record? Please clarify the statement.

We have rephrased the related sentence. There is no longer a need for a specific reference. We now use “ice extent” instead of “sea ice,” and the implication that sea ice should impact the benthic δ18O record has been removed. It now reads as follows:

“From 3.65 to 3.5 Ma, the benthic δ18O indicate a long-term decreasing trend in ice volume (Fig. 4a), implying a reduction in ice extent and the ice-albedo effect.”

Page 16
Line 393: The meaning of the last part of this sentence is not clear. Line 394: why/based on what? Line 395: role for what

We have rephrased the related sentences to solve the above several concerns. They now reads as follows (Line 376-380):

"However, the Mg/Ca-based summer SST does not show a corresponding trend to the NAC change. Additionally, the decrease in SubT (~0.5°C) is smaller than the change observed in the 3.65-3.5 Ma period (~1°C). These results suggest that the NAC's influence during this stage was less significant than in the 3.65-3.5 Ma period. Therefore, the significant decrease in the alkenone-based cold season SST appears not to be solely explained by the weakening NAC."

Line 399: volume
We have made the suggested change.

Line 404: could U1313 rather be impacted by the interplay between the STG and SPG? likes to the comment on how large (or small) the seasonal sea ice cover is likely to have been at this time.

Unlikely. The interplay between the STG and SPG would not have directly influenced the temperature variations at U1313 during our study interval. At present, U1313 is located near the northern boundary of the STG. In the studied interval, both alkenone and Mg/Ca-SST show warmer-than-present values, implying a northward extension of the STG. As a result, U1313 was closer to, and probably within, the STG. The NAC likely maintained a northeastward flow similar to the present, isolating the STG from the SPG. It is suggested that the first significant glacial incursion of subarctic front surface water above Site U1313 did not occur until ~2.6 Ma (Bolton et al., 2018).

However, this does not negate the significant influence of the ice-albedo effect on U1313 by altering atmospheric circulation, particularly during the cold season. For a detailed explanation, please refer to our previous response.